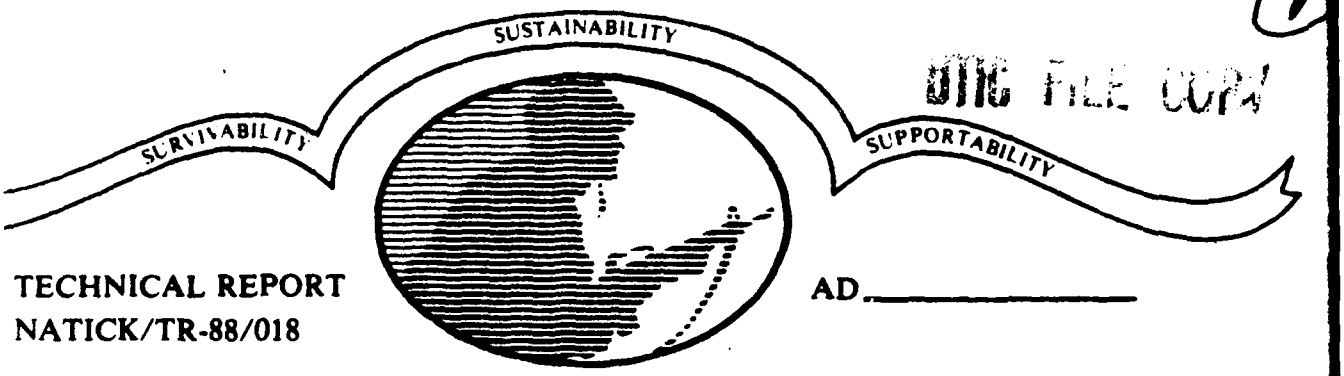

TECHNICAL REPORT
NATICK/TR-88/018

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EFFECTS OF STORAGE TIME AND TEMPERATURE ON NUTRITIONAL CONTENT OF FORTIFIED FRUITCAKE

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A storage study was conducted at U.S. Army Natick Research, Development, and Engineering Center to determine if fortified, thermoprocessed fruitcake would retain its acceptability and nutritional value in extended storage. This fruitcake is to be nutritionally adequate for use as a NASA contingency ration. Vitamins (A, C, E, B_6, B_{12}, folicin, and niacin), calcium, and magnesium were added to meet 100 percent of the Recommended Daily Allowance for males 22-35 years of age. Fruitcakes were stored for two years at 4°C and 21°C, and one year at 38°C. It was found to retain nutritional quality during storage and met requirements for most of the nutrients under test.

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PREFACE

The National Aeronautics and Space Administration (NASA) requested the U.S. Army Natick Research, Development, and Engineering Center (Natick) to develop a contingency ration that would meet and retain 100 percent of the Recommended Daily Allowance (RDA) for males 22 to 35 years of age, and maintain acceptability under storage at 4°C, 21°C and 38°C. Flexibly packaged, thermoprocessed fruitcake had been developed by Natick Research and Development Center for use in the Meal, Ready-to-Eat, a combat ration, and this formula was modified to meet these contingency ration criteria.

Fortified fruitcake was accepted by astronauts on Apollo 17, permitted on SkyLab as a Christmas treat, included on the Apollo-Soyuz menu, a component of Orbital Flight Test menus, and is available for shuttle flight menu use. Results from earlier storage studies indicated that although fruitcake retained consumer acceptability throughout storage, fortification levels of some nutrients were inappropriate. This report describes the results of a two-year follow-up study on fruitcake with some alterations in nutrient fortification levels.

The authors wish to acknowledge gratefully the contributions of Mrs. Nancy Kelley, Mr. Henry Russell, and Mr. Henry Morgan in the

production and packaging of the fruitcake; Mrs. Miriam Thomas and Mrs. Bonita Atwood for preparation of the vitamin and mineral premixes; Mr. Leon Klarman for his data analysis support; and, Ms. Patricia A. Kelsoe and Mrs. Elizabeth Ziomek for their dedicated typing support.

The work described in this report was performed at Natick for the National Aeronautics and Space Administration (NASA) under MIPR-T-9371A except that nutrient analyses (proximate, mineral, fatty acid and vitamin) were performed by Shankman Laboratories, Los Angeles, California, under contract No. DAAK60-79-D-0003.

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EFFECTS OF STORAGE TIME AND TEMPERATURE ON NUTRITIONAL CONTENT OF FORTIFIED FRUITCAKE

INTRODUCTION

In 1972 the National Aeronautics and Space Administration (NASA) requested that the U.S. Army Natick Research, Development and Engineering Center (Natick) develop a nutritionally complete fruitcake as a shuttle flight contingency ration to supply the Recommended Daily Allowances (RDA) for males 22 to 35 years of age.(1) The fruitcake was to remain acceptable throughout three years of ambient storage (21°C) and withstand short-time exposures to temperatures ranging from -18°C to 38°C. Analysis of nutrient fortified fruitcake selected by NASA for Apollo 17 revealed that certain nutrient levels were inadequate, even though consumer acceptance remained good.(2)

The work to meet NASA's requirement for a nutritionally complete fruitcake included a three-year storage study, which investigated the stability of fortified and unfortified thermoprocessed fruitcakes.(2) The results indicated that the concept of using fruitcake as a single food contingency ration was sound. A 700-g quantity of fruitcake met NASA's caloric requirements and was stable when stored at 21°C and at 38°C and provided RDA levels of magnesium, vitamin A, thiamin, riboflavin and pyridoxine. The study, however, recommended that the nutritional phase of the study be repeated for several reasons. It was found that the levels of vitamin A and niacin supplied in 700 g of fruitcake were two to four times the recommended dietary allowance, the 87% loss of ascorbic acid

during processing resulted in low initial levels of this vitamin and prevented its assessment in the fruitcake, and data were not collected on the stability of vitamins B12, E, and folic acid.

The storage study described in this report was conducted on a formulation of fruitcake improved to respond to the deficiencies described above. A determination was made as to the stability of fruitcake having reduced levels of vitamin A and niacin and increased levels of ascorbic acid, calcium, and riboflavin. In addition, data were obtained on the stability of folacin, vitamin B12, and vitamin E.

EXPERIMENTAL MATERIALS AND METHODS

Materials

The following nutrients were added to each batch (22.7 kg) of formulation of unfortified fruitcake (2) to produce a fortified product.

Calcium lactate (13% calcium)	66 g
Magnesium sulfate (20% magnesium)	15 g
Thiamin hydrochloride	200 mg
Riboflavin	150 mg
Niacin (nicotinic acid)	750 mg
Pyridoxine hydrochloride	150 mg
Vitamin A palmitate	386,000 IU
Vitamin E (DLα-tocopherol)	2,270 IU
Vitamin B12 (0.1% titration with mannitol)	454 mcg
Folacin (folic acid)	26,000 mcg
Ascorbic acid	24,600 mg

Compared to nutrient fortification levels in the 1973 to 1976 study, calcium was increased 340% and ascorbic acid was increased 100%. Vitamin A was reduced 70% and niacin was reduced 50%.

Special Mixing Procedures for Vitamin Fortified Fruitcake

Vitamin and mineral premixes were prepared by mixing granulated sugar with specific amounts of vitamins and minerals. Each vitamin or mineral was mixed with a small amount of sugar, then these quantities and the remaining sugar specified in the basic formula were combined using a Blakeslee mixer on low speed to produce the final premixes. These were refrigerated until added to the formulas. Each lot of the product was prepared, pouches were filled with six ounces of product, and thermo-processed in accordance with the Space Food Prototype Production Guide (see Appendix A of (2)). The vacuum packaging and pasteurization procedures specified in the Production Guide were not required.

Storage Conditions

Three nutrient fortified lots (A, B, C) of fruitcake were stored for up to two years at 4°C and 21°C, and for one year at 38°C. Withdrawal periods for nutrient analyses of samples at specified storage temperatures and intervals are given in Table 1.

Table 1. Intervals for Withdrawal of Fortified Fruitcake (Lots A, B, C)

STORAGE TEMPERATURE	MONTHS IN STORAGE			
	0	6	12	24
Initial	A, B, C			
4° C				A, B
21° C		A, B, C	A, B, C	A, B
38° C		A, B, C	A, B, C	

Sampling Procedure and Nutrient Analyses

Initial Samples. Initial (baseline) samples were analyzed for proximate, mineral, fatty acid, and vitamin content. Initial samples consisted of a total of 30 pouches, 10 from each of the three lots of fruitcake. Subsequently, each 10-pouch aggregate was randomly divided into five 2-pouch samples. Each initial sample was then composited and analyzed for proximate and mineral content (single analysis) and for vitamins and fatty acids (duplicate analysis).

Stored Samples. Six pouches were randomly drawn from storage in accordance with the test plan for nutrient analysis (Table 1). Subsequently, each 6-pouch aggregate was randomly divided into three

2-pouch samples, which were composited and analyzed. Stored samples were analyzed in duplicate for vitamin, moisture, and fat content. Previous experience in analysis of stored products indicated that mineral, proximate, and fatty acid content does not change significantly over time. All nutrient analyses were performed by Shankman Laboratories (3), which utilized standard methods specified in the contract and in the Appendix. Standard statistical methods, analysis of variance (ANOVA) and Duncans Multiple Range Test were used in data analyses. No samples from the original A, B, C lots were commingled in the analyses.

RESULTS AND DISCUSSION

All nutrient data were calculated on an as-is moisture-free, and combined moisture-free, fat-free basis. Statistical analyses on each set of data were performed using the ANOVA program. Since the trends in nutrient levels were similar as a function of time for all three analyses, all results are being reported on an as-is basis.

Proximate and Mineral Analyses

The results of the proximate and mineral analyses conducted on the intitial samples are summarized in Table 2. An analysis of variance performed on initial samples indicated that there were significant differences in moisture, fat, iron, and potassium content between the three lots. As a result, it was decided to treat each lot separately

Table 2. Initial and Composite Proximite and Mineral Content of Three Lots of Fortified Fruitcake per 100 grams

	LOTS			
	A	B	C	Composite
Moisture, g	16.26 +/- 0.23 c	16.98 +/- 0.09	17.35 +/- 0.22 a	16.86
Protein, g	7.50 +/- 0.23	7.55 +/- 0.23	7.47 +/- 0.18	7.50
Fat, g	18.75 +/- 1.08 a	16.34 +/- 0.40 b	15.76 +/- 0.64 b	16.95
Ash, g	1.81 +/- 0.05	1.81 +/- 0.05	1.83 +/- 0.03	1.82
Calcium, mg	142.00 +/- 4.00	145.00 +/- 4.00	144.00 +/- 2.00	144.00
Phosphorus, mg	178.00 +/- 5.00	180.00 +/- 4.00	177.00 +/- 6.00	178.00
Iron, mg	1.74 +/- 0.05 b	1.88 +/- 0.08 a	1.74 +/- 0.05	1.78
Sodium, mg	276.00 +/- 19.00	279.00 +/- 21.00	286.00 +/- 14.00	280.00
Potassium, mg	363.00 +/- 11.00 b	373.00 +/- 7.00 ab	381.00 +/- 10.00 a	372.00
Magnesium, mg	58.40 +/- 2.6	60.00 +/- 1.58	58.8 +/- 0.84	59.06
Chloride as NaCl, g	0.52 +/- 0.05	0.51 +/- 0.02	0.49 +/- 0.05	0.50
Carbohydrate ,g (by difference)	55.68	57.32	57.59	56.87
Calories, Kcal*	397.10	382.97	378.46	384.00

An analysis of variance was performed for each nutrient. Means for each nutrient followed by different letters are significantly different ($p <= 0.05$) as determined by Duncan's Multiple Range Test.

* Specific energy values (SEV) used to calculate calories were derived from specific factors for calculating energy values.

	SEV (Kcal/g)
Protein	3.63
Fat	8.59
Carbohyrrates	3.75

throughout the study. When viewing the composite proximate and mineral content for the three lots of fortified fruitcake, multiplication of the mean values of the nutrients by seven shows that the RDAs for calcium, magnesium and iron are met by one contingency ration (700 g) of fruitcake. One 700-g ration of fruitcake supplies 2,688 calories, and provides 93% of the RDA for calories. A 755-g ration of fruitcake would supply the RDA of 2,900 calories. Protein provides 7.1 percent of the total calories and therefore meets NASA's requirement for a contingency food. The 52.5 g of protein provided by 700 g of fruitcake yields 94% of the RDA for protein. The estimated safe and adequate daily dietary intakes for sodium, potassium, and chloride are met by 700 g of fortified fruitcake.(1)

Fatty Acid Analyses

Table 3 summarizes the data on fatty acid composition of fats as percent of total fatty acids for each lot of fortified fruitcake. These values are consistent with those from the fortified and unfortified fruitcakes analyzed in the 1973-1976 study.(2)

The average fat content of a 100-g sample of fruitcake was found to be 16.95 g (Table 2). This provided 38% of the total calories as fat. Fatty acids are estimated to be 90% of the total fat in the sample according to a standard method.(4) The average fat content of the fruitcake sample was adjusted by the factor 0.9 to estimate the amount of fatty acids per 100 g of product. This means there is an estimated 15.25 g of fatty acids per 100 g of fruitcake.

Table 3. Percent of Total Fatty Acids, as Fatty Acids, in Fortified Fruitcake*

Fatty Acids	Myristic Acid 14:0	Palmitic Acid 16:0	Oleic Acid 18:1	Linoleic Acid 18:2	Arachidic Acid 20:0
LOT A	0.46 + 0.05	14.28 + 0.94	60.44 + 0.67	22.04 + 1.22	2.74 + 0.97
LOT B	0.40 + 0.00	13.23 + 0.48	56.38 + 2.05	26.45 + 1.09	3.53 + 1.55
LOT C	0.40 + 0.00	13.20 + 0.22	56.48 + 1.04	26.38 + 1.10	3.55 + 0.19

* Mean +/- Standard Deviation (N=5)

Table 4 summarizes the mean fatty acid content in grams per 700 g of fruitcake and also expresses each fatty acid as a percentage of total calories. The saturated fatty acid content of the fruitcake is 15.7% of the total fat and provides a 5.68% of total calories. The monosaturated fatty acid content, primarily oleic acid, is 52.0% of total fat and contributes 20.0% of total calories. Linoleic acid comprises 22% of total fat and contributes approximately 9% of total calories. This meets the National Council recommendation that 8 to 10% of total calories shuold be provided by polyunsaturated fatty acids.(1) The fortified fruitcake previously studied had 4.7% stearic acid, 63% oleic, 20% linoleic, and 0.8% linoleic acid.(2)

Table 4. Fatty Acids in One Contingency Ration (700 grams) of Fortified Fruitcake

	Saturated			Monounsaturated	Polyunsaturated
Fatty Acids	Myristic Acid 14:0	Palmitic Acid 16:0	Arachidic Acid 20:0	Oleic Acid 18:1	Linoleic Acid 18:2
Grams per Serving	0.45	14.49	3.49	61.67	26.64
Percent of Total Fat	0.37	12.21	2.94	51.97	22.45
Percent of Total Calories	0.14	4.71	1.13	20.04	8.66

Vitamin Analyses

The mean values and standard deviations of vitamin content for each individual lot of fruitcake, under all storage conditions, are shown in Table 5. The analysis of variance performed to judge the significance of differences between vitamin content of the three lots indicated no differences in vitamin levels between the three lots; however, as in the earlier study, the standard deviations for vitamin A were fairly large, being 24%, 18%, and 17% of the mean values for lots A, B, and C, respectively. Also the standard deviations for vitamin B12 ranged from 7 to 23% of the mean values. The large standard deviations reenforced the decision to redesign the test plan so that the lots would not be mixed but would be analyzed separately at each withdrawal. This decision restricted the duration of the study because of insufficient samples of Lot C.

e 5. Vitamin Content of Three Lots (N=3) of Fortified Fruitcake, per 100 g

		4° C	21° C			38° C	
	Initial	24 MOS	6 MOS	12 MOS	24 MOS	6 MOS	12 MOS
Vitamin A, IU							
Lot A	915 ± 221	950 ± 49	713 ± 19	616 ± 6	1009 ± 88	790 ± 100	647 ± 58
Lot B	1135 ± 206	1049 ± 40	768 ± 43	790 ± 61	1175 ± 34	877 ± 81	930 ± 43
Lot C	1050 ± 187	NW *	668 ± 215	784 ± 56	NW	730 ± 31	708 ± 13
Thiamin, mg							
Lot A	0.54 ± 0.03	0.29 ± 0.006	0.46 ± 0.006	0.34 ± 0.008	0.27 ± 0.008	0.31 ± 0.02	0.17 ± 0.01
Lot B	0.63 ± 0.05	0.30 ± 0.03	0.49 ± 0.02	0.44 ± 0.05	0.29 ± 0.008	0.32 ± 0.04	0.22 ± 0.04
Lot C	0.62 ± 0.08	NW	0.48 ± 0.04	0.43 ± 0.06	NW	0.30 ± 0.02	0.23 ± 0.01
Riboflavin, mg							
Lot A	0.54 ± 0.03	0.47 ± 0.01	0.54 ± 0.05	0.69 ± 0.01	0.47 ± 0.03	0.43 ± 0.03	0.58 ± 0.06
Lot B	0.55 ± 0.03	0.39 ± 0.05	0.56 ± 0.06	0.66 ± 0.02	0.40 ± 0.009	0.52 ± 0.15	0.67 ± 0.06
Lot C	0.58 ± 0.03	NW	0.56 ± 0.02	0.68 ± 0.06	NW	0.54 ± 0.05	0.64 ± 0.03
Niacin, mg							
Lot A	3.35 ± 0.27	3.3 ± 0.22	3.20 ± 0.2	3.57 ± 0.25	3.37 ± 0.25	3.32 ± 0.03	3.80 ± 0.13
Lot B	3.39 ± 0.24	3.6 ± 0.27	3.35 ± 0.09	3.60 ± 0.22	3.63 ± 0.27	3.63 ± 0.40	3.87 ± 0.32
Lot C	3.44 ± 0.26	NW	3.57 ± 0.08	3.88 ± 0.23	NW	3.40 ± 0.12	3.55 ± 0.25
Pyridoxine, mg							
Lot A	0.56 ± 0.02	0.58 ± 0.02	0.53 ± 0.02	0.59 ± 0.04	0.59 ± 0.053	0.52 ± 0.03	0.54 ± 0.04
Lot B	0.55 ± 0.06	0.60 ± 0.07	0.60 ± 0.04	0.60 ± 0.03	0.54 ± 0.006	0.55 ± 0.05	0.55 ± 0.07
Lot C	0.58 ± 0.05	NW	0.57 ± 0.006	0.63 ± 0.03	NW	0.53 ± 0.01	0.56 ± 0.01
Folacin, µg							
Lot A	100 ± 11	94 ± 14	58 ± 7	52 ± 8	44 ± 27	7 ± 4	6 ± 2
Lot B	100 ± 9	85 ± 43	95 ± 37	65 ± 18	45 ± 6	9 ± 3	5 ± 3
Lot C	98 ± 6	NW	50 ± 2	51 ± 10	NW	7 ± 2	3 ± 1

Table 5. Vitamin Content of Three Lots (N=3) of Fortified Fruitcake, per 100 g (Cont'd)

		4° C	21° C			38° C	
	Initial	24 MOS	6 MOS	12 MOS	24 MOS	6 MOS	12 MOS
Vitamin B12, µg							
Lot A	0.16 ± 0.04	0.08 ± 0.007	0.07 ± 0.004	0.08 ± 0.005	0.08 ± 0.14	0.07 ± 0.001	0.07 ± 0.01
Lot B	0.13 ± 0.02	0.09 ± 0.03	0.08 ± 0.008	0.09 ± 0.006	0.06 ± 0.007	0.08 ± 0.007	0.18 ± 0.03
Lot C	0.16 ± 0.05	NW	0.08 ± 0.006	0.18 ± 0.01	NW	0.07 ± 0.01	0.15 ± 0.01
Vitamin E, mg							
Lot A	3.63 ± 0.25	2.25 ± 0.05	2.80 ± 0.52	1.52 ± 0.16	2.35 ± 0.10	3.40 ± 0.10	1.60 ± 0.15
Lot B	3.50 ± 0.42	2.20 ± 0.05	2.58 ± 0.41	1.53 ± 0.13	2.37 ± 0.08	4.05 ± 0.39	1.57 ± 0.03
Lot C	3.27 ± 0.74	NW	2.27 ± 0.21	1.57 ± 0.03	NW	3.60 ± 0.21	1.42 ± 0.03

* NW : (No Withdrawal) Samples in Lot C were not stored for 24 months.

NOTE : Since ascorbic acid was negligible at 6 months, analysis after this time was discontinued. Initial levels of ascorbic acid are reported in Table 8.

Table 6 presents the mean vitamin content (per 100 g) of the three lots of fruitcake assayed after each withdrawal. The mean percent retention of vitamins after storage is shown in Table 7. Table 8 compares the initial nutritional content of the contingency fruitcake ration against the RDA and the vitamin content after 12 and/or 24 months storage. The impact of storage on each vitamin is discussed separately.

Vitamin A. Vitamin A retention was greatest at 4°C, being 98% after two years storage. The standard deviations for vitamin A are variable. However, the detectable limits of the method used are ± 100 IU, so standard deviations of 200 to 300 IU are not considered unusual in a nonhomogeneous mixture such as fruitcake. The reason for the high levels of vitamin A measured after two years storage at 21°C is not clear. These increased values do not differ significantly from initial measures of vitamin A, but do differ from values determined at 6 and 12 months. Possible explanations for the apparent increase in vitamin A were offered previously (e.g., differences due to procedures, changes in personnel, or the development of an interfering compound in storage that results in an apparent increase and may even mask a decrease of the vitamin during storage).(2) Based on data in Table 8, the RDA of 5,000 IU will be met by a 700-g contingency ration of fruitcake under each storage condition.

Thiamin. Significant decreases in thiamin occurred over time during storage at 4°C, 21°C and 38°C. Average thiamin retention following two years of storage at 4°C and 21°C are 56% and 48%, respectively.

Table 6. Mean Vitamin Content of Fortified Fruitcake After Storage, per 100 grams

MONTHS IN STORAGE	Vitamin A IU	Thiamin mg	Riboflavin mg	Niacin mg	Pyridoxine mg	Folacin mcg	Vitamin B12 mcg	Vitamin E mg
INITIAL[a]	1033	0.59	0.56	3.39	0.56	99	0.150	3.46
4°C								
24[b]	999	0.30	0.43	3.46	0.59	89	0.085	2.22
24°C								
6[c]	716	0.47	0.55	3.38	0.56	68	0.076	2.55
12[c]	730	0.40	0.67	3.68	0.60	56	0.110	1.54
24[b]	1092	0.43	0.56	3.50	0.56	44	0.070	2.36
38°C								
6[c]	799	0.31	0.49	3.45	0.53	8	0.076	3.68
12[c]	762	0.20	0.63	3.74	0.55	5	0.130	1.57

[a] Average of 3 lots of Fruitcake (5 samples per lot ananyzed in duplicate)
[b] Average of 2 lots of Fruitcake (3 samples per lot analyzed in duplicate)
[c] Average of 3 lots of Fruitcake (3 samples per lot analyzed in duplicate)

Table 7. Mean Percent Retention of Vitamins in Fortified Fruitcake

STORAGE TEMP	STORAGE TIME MONTHS	Vitamin A	Thiamin	Riboflavin	Niacin	Pyrodoxine	Folacin	Vitamin B12	Vitamin E
4°C	24	98	51	79	103	106	89	60	62
21°C	6	70	80	99	99	100	69	52	73
	12	71	68	122	108	108	56	77	44
	24	105	48	80	92	102	44	48	56
38°C	6	78	52	89	102	95	8	50	107
	12	73	34	113	110	98	5	86*	44

NOTE: The percent retention reflects the difference between the initial values and the value at each specified storage time.

Calculation of nutrient composition of unfortified fruitcake showed base levels of nutrients were approximately 10% or less of fortification levels, thus percent vitamin retention reflects retention of the fortification vitamins.

* Derived from data on lots A and B only a the lot C mean value is 1 1/2 times the value of its initial sample.

Table 8. Comparison of RDA with Nutrient Levels Provided by a 700 g Ration of Fortified Fruitcake Before and After Storage.

			Storage Time and Temperature			
			4°C	21°C		38°C
NUTRIENT	MALES 22-35 YEARS RDA REQUIREMENTS 1980	INITIAL[a]	24 MOS[b]	12 MOS[c]	24 MOS[b]	12 MOS[c]
Energy K/cal	2900.00	2688.00				
Protein g	56.00	52.55				
Calcium mg	800.00	1006.00				
Phosphorous mg	800.00	1248.00				
Magnesium mg	350.00	413.00				
Iron mg	10.00	12.50				
Sodium mg	1100 - 3300[d]	1962.00				
Potassium mg	1875 - 5625[d]	2606.00				
Chloride mg	1700 - 5100[d]	2141.00				
Vitamin A IU	5000.00	7233.00	6996.00	5110.00	7644.00	5332.00
Vitamin E mg	10.00	24.20	15.57	10.78	16.52	10.71
Thiamin mg	1.50	4.17	2.10	2.82	1.96	1.45
Riboflavin mg	1.70	3.89	3.01	4.73	3.04	4.41
Niacin mg	19.00	23.70	24.22	25.78	24.50	26.18
Pyridoxine mg	2.20	3.94	4.13	4.24	3.95	3.85
Folacin mcg	400.00	693.00	623.00	392.00	311.00	32.60
Vitamin B12 mcg	3.00	1.05	0.59	0.59	0.49	0.91
Ascorbic Acid mg	60.00	36.26				

[a] Average of 3 lots fortified Fruitcake (5 samples per lot analyzed in duplicate)
[b] Average of 2 lots fortified Fruitcake (3 samples per lot analyzed in duplicate)
[c] Average of 3 lots fortified Fruitcake (3 samples per lot analyzed in duplicate)
[d] Estimated safe and adequate daily dietary intakes recommended dietary allowances - National Research Council, 1980

Based on data in Table 8, the RDA for thiamin of 1.5 mg will be met by 700 g of fruitcake under practically all storage conditions. Although only 34% of thiamin is retained after one year of storage at 38°C, 96% of the RDA will still be supplied by a 700-g ration of fruitcake.

Riboflavin. There is a great deal of variability in the measured riboflavin content after storage. Average riboflavin content after one year storage at 21°C and 38°C seems to increase to 122% and 113% when compared to initial values. However after two years storage at 4°C and 21°C the retention of riboflavin is, respectively, 79% and 80% of the initial level (Table 7). It has been reported that large fluctuations in riboflavin content often occur in assays after storage.(5, 6) Also, since the lots of fruitcake produced were pilot batches, and the actual amounts of each vitamin added were very small, it is possible that all the vitamins were not equally distributed among all fruitcake samples, especially since fruitcake is a nonhomogeneous mixture. This may explain inconsistencies in riboflavin content as well as fluctuations in other nutrient levels. In spite of this variation, riboflavin seems relatively stable, and one 700-g ration of fruitcake meets the RDA of 1.7 mg for riboflavin under all storage conditions.

Niacin. Niacin content remained stable throughout all storage conditions. The small increases and decreases reported are not statistically significant. The RDA for niacin of 19 mg is met by one 700-g ration of fruitcake.

Pyridoxine. Pyridoxine remained stable at all temperatures and storage periods. A 700-g ration of fruitcake meets the RDA of 2.2 mg pyridoxine.

Vitamin B12. Average vitamin B12 retention after two years of storage at 4°C and 21°C after six months at 38°C are 60%, 48%, and 50%, respectively. However, as Table 5 shows, with two exceptions, the mean values reported for Vitamin B12 in stored fruitcake are similar regardless of storage temperature and duration of storage time. The exceptions are the unexpectedly high mean values for some of the lots stored 12 months at 21°C and 38°C. These data point to the possibility of problems in the analytical procedure, some of which are highlighted in reference 7. In any case the true effect of storage time and temperature on B12 in fruitcake is at best uncertain.

Even as initially sampled, the 700-g ration of fruitcake provides only 35% of the RDA of 3 mcg for vitamin B12. The prescribed fortification level of vitamin B12 provided for 14 mcg per 700-g ration; however, more than 90% of vitamin B12 was lost during processing. The fact that retention of vitamin B12 after processing was very poor and the possibility of some losses of vitamin B12 after storage suggests that fruitcake may not be an appropriate carrier for vitamin B12 fortification. There may have been a mutually destructive interaction of vitamin B12 and ascorbic acid (8).

Folacin. Folacin retention after two years of storage at 4°C and 21°C is 89% and 44%, respectively. However, at 38°C, folacin retention was

extremely poor, being only 8% and 5%, respectively, following 6 and 12 months storage. The standard deviations for folacin are large and variable. It is recognized that folacin analyses can be quite variable (7). From these data, however, the RDA for folacin is still met after two years storage at 4°C. Fruitcake stored at 21°C for one year meets 98% of the RDA, and after two years meets 77% of the RDA. Fruitcake stored for six months at 38°C contains only 13% of the RDA for folacin. Based on the latter data, retorted cake items such as NASA fruitcake are not recommended as carriers for folic acid fortification, unless the product can be stored at temperatures that will not exceed 21°C.

Vitamin E. Average vitamin E retentions after two years of storage at 4°C and 21°C, and one year at 38°C are 62%, 56%, and 44%, respectively, and differ significantly from initial values. Tables 5, 6, and 7 show that the values reported for vitamin E after one year of storage at 21°C are comparable to those reported after one year storage at 38°C. These tables also show that the values reported for all samples stored six months at 21°C are considerably lower than those stored 6 months at 38°C. In this case the latter values appear high. The authors believe that these results strongly indicate that a problem may have occurred in the analytical procedure. Such problems are not unusual in the chemical procedure used.(7) Fluctuations in data such as those found can not be explained and they also preclude valid predictions regarding the stabiltiy of vitamin E in fruitcake. They do point to the need for more work to ascertain that the method specified for analysis is

reliable for a product such as fruitcake. The oil used in making the fruitcake will provide other tocopherols, notably γ -tocopherols, which will be included in a chemical determination of vitamin E. The chemical method really determines total tocopherols; hence, prior fractionation of tocopherols is required. Based on these data, however, the RDA for vitamin E was met at each withdrawal.

Ascorbic Acid. Ascorbic acid levels in the premix, although double the levels used earlier(2) and twelve times the RDA, were still not adequate to compensate for all processing losses. Initial samples of fruitcake contained 5.18 mg of ascorbic acid per 100 g and would thus provide 36 mg of ascorbic acid per 700-g ration, which is only 60% of the RDA for ascorbic acid. Analysis after only six months storage at 21°C and 38°C showed ascorbic acid losses to be 83% and 98%, respectively. Thus analysis for ascorbic acid was discontinued after six months. It has been reported by other investigators that ascorbic acid is destroyed during storage by oxidation.(5) Also, the presence of vitamin B12 may contribute to oxidative loss of ascorbic acid.(8) Removal of vitamin B12 may lead to increased stability of ascorbic acid during storage. Vacuum sealing or nitrogen flushing before processing may limit oxidation of ascorbic acid.

CONCLUSIONS

Fortified fruitcake is an adequate carrier of vitamin A, thiamin, riboflavin, niacin, pyridoxine, and vitamin E. It is not adequate for vitamin B12, folacin, and ascorbic acid.

RECOMMENDATIONS

Future work should concentrate on finding appropriate carriers and adjuncts, such as encapsulation, for ascorbic acid, folacin, and vitamin B12 in fortified products that are thermally processed or are to be stored at nonrefrigerated temperatures.

REFERENCES

1 Food and Nutrition Board, National Academy of Sciences-National Research Council, Recommended Dietary Allowances. Ninth Revised Edition, 1980.

2 Klicka, M. V., D. E. Sherman, B. Atwood, W. Swantak, K. M. Thompson, M. T. Branagan. Nutritionally Fortified Fruitcake (Thermoprocessed, Flexibly Packaged) Developed for Shuttle Flight Use. NATICK/TR-82/004 June 1981. (AD A129 878)

3 Shankman Laboratories, Los Angeles, CA, Contract No. DAAK60-79-D-0003, Letter Reports.

4 Murphy, E. W., L. Page and P. C. Koon. Lipid Components of Type A School Lunch, J. Am. Diet. Assoc., 56:504 (1970).

5 Feaster, J. F., M. D. Tompkins and W. E. Pearce. Effect of Storage on Vitamins and Quality in Canned Foods. Food Research 14:25, 1949.

6 Brenner, S., V. O. Wodicka and S. G. Dunlop. Effect of High Temperature Storage on the Retention of Nutrients in Canned Foods. Food Technology 2:207, 1948.

7 Association of Vitamin Chemists, Inc., Methods of Vitamin Assay, Third Edition, 1966.

8 DeRitter, E. Vitamins in Pharmaceutical Formulations. J. Pharm. Sci. 71:1073, (1982).

9 Horowitz, W. Official Methods of Analysis of the American Association of Official Analytical Chemists, Assoc. Off. Anal. Chem. 13th ed. 1980.

10 Perkin-Elmer, Analytical Methods for Atomic Absorption Spectrophotometry, a technical manual (1964).

11 Binnerts, W. T. Determination of Iodine in Milk. Anal. Chimica Acta., 10:78 (1954).

12 Bro-Rasmussen F. and W. Hjarbe. Determination of Tocopherol by Chromotography on Secondary Magnesium Phosphate. Acta. Chem. Scand., 11:44 (1957).

13 Dick-Bushnell, M. W. Column Chromotography in the Determination of Tocopherol: Florisil, Silicic Acid and Secondary Magnesium Phosphate. J. Chromato, 27:96 (1967).

APPENDIX

AOAC METHODS OF ANALYSES (9)

Assay	References
Moisture	As appropriate
Total Fat	Soxhlet/acid hydrolysis
Protein	2.057
Crude Fiber	7.065
Ash	14.006
Phosphorus	2.021
Chloride as NaCl	18.034
Cholestrol	14.149
Fatty Acid Profile	28.057
Total Fatty Acids	28.029
Atomic Absorption Spectrophotometer	
Calcium	(10)
Iron	(10)
Sodium	(10)
Potassium	(10)
Magnesium	(10)
Other	
Iodine	(11)

Method of Vitamin Assay	Pages in Reference (7)
Vitamin A	70-79
Carotene	104-115
Thiamin	127-142
Riboflavin	158-164
Niacin	172-176
Pyridoxine	212-219
Vitamin E (also 12, 13)	366-391
Ascorbic Acid	299-306
Folacin	227-234
Vitamin B12	262-270